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ORIGINAL ARTICLE

Landscape diversity and associated coping strategies during food shortage periods: evidence from the Sudano-Sahelian region of Burkina Faso

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Abstract The importance of forest resources for rural communities' livelihoods has increasingly been recognized over the last three decades. Forests provide food, generate incomes, provide supporting (nutrient cycling, pollination), and regulating (climate, diseases, water regulation and purification) services for agriculture, in addition to their aesthetic, cultural and spiritual role. However, most of the studies on forest resource use do not focus on the role of landscape organization in addressing the impact of climate variability and the risk of food insecurity. This study aims to examine the contribution of woodlands and trees towards decreasing the risk of food insecurity and the importance of landscape structure and composition in coping with food shortages. It took place in two villages in Burkina Faso, on both ends of the woodlands and tree-cover spectrum. We demonstrate that in both landscapes, ecosystem goods, such as shea nuts and fuelwood, represent a safety net for households during food shortage periods. We demonstrate that households shape their adaptive strategies differently depending on the resources available and the structure of the landscape. People living in a landscape with a savannah matrix (Sorobouly) rely on fuelwood trade to purchase cereals, while those living in a landscape with a parkland matrix (Kalembouly) rely on shea nuts. Agricultural, environmental and climate change policies that reinforce the rights of the most vulnerable to access key resources provided by these landscapes and development programs which assure their sustainable use will simultaneously enhance food security and increase their adaptive capacity in the face of climate change and variability.

Keywords Adaptive strategies · Climate variability · Landscape diversity · Forest resource · Food shortage

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Introduction

The importance of forest resources for rural livelihoods has increasingly been recognized during the last three decades (Djoudi et al. 2015; Ndoye and Tieguhong 2004; Shackleton and Shackleton 2004; Shackleton et al. 2007; Vedeld et al. 2007; Wunder 2001). Forests are important for crops (Verchot et al. 2007; Garrity et al. 2010); they provide food, fuel, fodder and facilitate income generation. In poor, rural communities with less income opportunities, people often use forest resources in times of crisis (Fisher and Shively 2005). In Africa, rural people, particularly the most vulnerable, rely on forests for their livelihoods (Colfer et al. 2006; Harris and Mohammed 2003; Hautdidier and Gautier 2005; Ros-Tonen and Wiersum 2003). In the context of low employment opportunities and difficulties in accessing land, many of the rural poor collect forest products for their own

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use (Powell et al. 2011; Ros-Tonen and Wiersum 2003; Somorin 2010), or for additional income generation (Angelsen and Wunder 2003; Arnold et al. 2011; Egoh et al. 2012; Fisher et al. 2010; Warner 2000; Yemiru et al. 2010). The importance of forest resources in rural communities is particularly significant during food shortage periods (Fisher et al. 2010; Pramova et al. 2012b; Vinceti et al. 2008). Despite this evidence, forest resources are not adequately considered in the poverty alleviation policies of most developing countries (Oksanen and Mersmann 2003), including those in sub-Saharan Africa (McConnell 2008) and are rarely included in adaptation plans and projects (Pramova et al. 2012a). The poor are the most affected by food insecurity due to climate variability, particularly in the Sudano-Sahelian area. In this drought-prone area, food availability is influenced by temperature and rainfall variations that create crop failures. With the predicted future impacts of climate change, populations are likely to face such events with increased severity and frequency, with the consequent impacts on their food security (GIEC 2007). There is some evidence on the role of forest resources in buffering food shortage effects, but it is important to link this safety net to the landscape structure and available resources. Landscapes in the Sahelian region are increasingly changing due to agricultural practices that remain mainly extensive and where cotton is cultivated as a cash crop in rotation with maize, sorghum or millet. These practices result in the conversion of more areas of savannah into parkland, with a tree density that is partly determined by the farmers' level of mechanization (Traoré et al. 2007), essentially based on draft power. On the other side, studies in the Sahel (Gautier et al. 2006) show that when savannas are shrinking, farmers who rely on tree products attempt to compensate the important loss in trees ecosystem services by increasing tree density in the parklands.

This paper first aims to confirm that tree resources from woodlands, fallows and parklands are a safety net for vulnerable households in periods of food shortage in the Sudano-Sahelian area in all landscape structures. Second, it aims to demonstrate the link between the landscape and available tree resources. It shows how the adaptive strategies to cope with food shortage linked to climate variability are constrained and shaped by the structure and composition of the landscape, particularly for those poorer households at high risk of food insecurity.

Study areas

This study was conducted in southwest Burkina Faso, in the Balé province (Fig. 1) between 2012 and 2014.

The two villages selected are located about 12 km apart; both have a common social history and similar agroclimatic conditions, with a mean annual rainfall of 925 ± 157 mm in the period 1990–2011, but they are different in terms of landscape composition and structure. Sorobouly's landscape is composed of a savannah matrix with a population of 609 in 2006 (24 inhabitants per km^2); Kalembouly's landscape has an agricultural matrix with trees scattered in the fields. This type of land cover is referred to as parkland. Kalembouly's population was 1471 in 2006 (69 inhabitants per km^2) (RGPH 2006). Both villages belong to the Winnien ethnical group and originate from the same mother village. They are both in the rural municipality of Siby, close to Boromo city.

A preliminary workshop allowed us to characterize the main features of these villages' agrarian systems and livelihoods. Agriculture is the main livelihood activity in both villages. Sorghum, maize and millet are the main food crops, while cotton and sesame are the main cash crops. These rainfed crops (cotton, maize, millet) are cultivated during the rainy season, generally from May to October usually in rotation and in fields scattered with mature trees that we will term "parkland" in the rest of this paper. Livestock (oxen, sheep, goats and increasingly, cattle) occupy the second rank among Winniens' livelihood activities. The Winniens usually breed their animals (e.g., cattle, small ruminants, pigs and poultry) at home, but some households invest in livestock (mostly cattle) that they entrust to the Fulani people to look after; the Fulani live at the edge of the villages and herding is their main activity. In addition to cultivation and husbandry, local people gather, use and sell forest and tree products such as fuelwood, shea nuts and butter, *néré* (*Parkia biglobosa*) fruit, as well as other forest fruits, leaves and roots from Savannah woodlands and from parklands. Generally, forest and tree product-related activities are the responsibility of women and children, except for tree cutting and fodder gathering, which are carried out by men. The rights of access to and use of tree products are linked to an individual's social position and social capital as well as to the tenure status of the landscape element where the products are gathered from. More restrictions of access exist when land has been allocated by founding lineage and has already been cultivated (including fallows). The rights of access to and use of products from savannahs are more flexible but become more restricted for the non-founding lineages with growing human pressures. In addition, state ownership of land overlaps with customary rights and this increases pressure on the poorest to use forest and tree products.

Methods

Two methods were used to study the relationship between landscape diversity and adaptive strategies used by vulnerable households in food shortage periods. The first

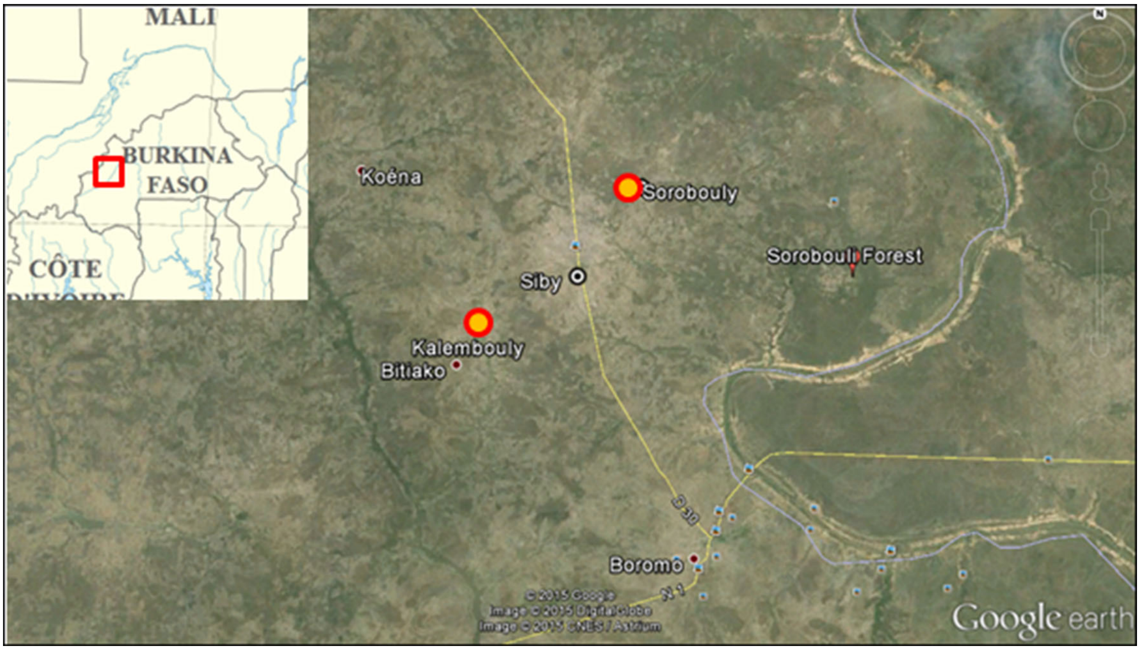

Fig. 1 Study area (©2015Google; Image©2015 DigitalGlobe; Image©2015 CNES/Astrium)

method is a characterization of the landscape at the village territory scale and the forest resources it contains. The second method is a household survey during a food shortage period including an assessment of the adaptive strategies households used to cope with the food shortages.

To assess landscape and forest resources, we delineated the two villages' territories with village representatives in May 2012. We then used a grid of 100 m in the delineated territories. Following parallel transects with a GPS, we identified the limits between the different components of landscape. We then combined this information with remote sensing data and field observations to finalize the land-cover and land-use maps of the two villages (Fig. 2), followed by an inventory of forest resources using a systematic sampling plan (Gautier and Karr 2000) with plots of 0.5 ha in the parkland area (50 m radius) and plots of 0.1 ha in the savannah and fallow areas (12 m radius).

The area of the villages' territories and those of the different ecosystems were calculated using the extension compiled theme tools of ArcView software. The species richness is the number of tree species found in each village territory. Mean trees densities per hectare were calculated for each ecosystem type. We calculated also the standard deviation in order to highlight the variation of tree densities around the mean.

A total of 60 households were randomly selected from each village on the basis of focus group workshops for the survey and the assessment of adaptive strategies. The household head and one of his wives were interviewed, yielding a total sample of 120 surveys (60 with men and 60 with women) per village.

The most common food security valuation approach is based on anthropometrics measures developed by FAO and WHO. This approach has been criticized by some authors because of its difficulty in implementing it in the field (Maxwell 1996; Payne and Lipton 1994). Our approach in this study is based on the approaches of Janin and Martin-Prevel (2006) in Burkina Faso, which highlight households' capacity to manage the risk of food insecurity. In the Sudano-Sahelian area, food insecurity usually occurs during food shortage periods, a period in the cropping season when cereal granaries become empty until the next harvest. Based on preliminary participatory observations, we identified the time when the food reserves from the last agricultural year were completely consumed (empty granaries) as the first indicator of risk of food insecurity. In response to the risk of food insecurity, several strategies were implemented at household level, among which food purchases and income diversification (Janin 2008) were the most common. We collected the information related to those strategies during the household surveys.

Household surveys were carried out in order to take into account both the temporality and seasonality effects (Janin 2003). We carried out the surveys during two successive crop-growing periods (from July 2012 to October 2012 [FSP2012] and from July 2013 to October 2013 [FSP2013]). The risk of food shortage was higher at the end of these periods. In order to compare the results, we also conducted surveys just after the harvest periods

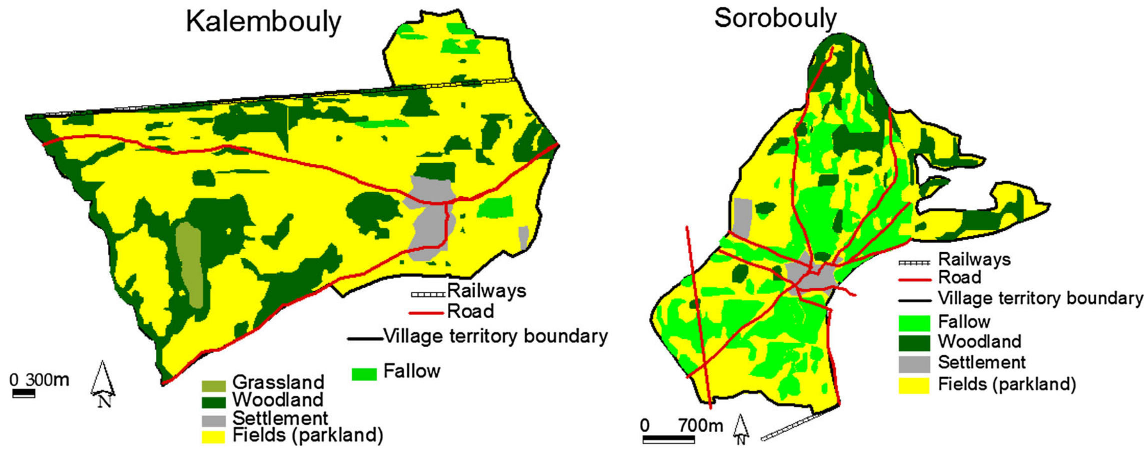

Fig. 2 Land-cover and land-use maps of the two villages

(January 2013 and January 2014) and during the dry season (April 2013 and May 2014). January 2013 and April 2013 were known as NFSP2013, and January 2014 and May 2014 were known as NFSP2014. During these periods, we interviewed the head of households once each month and 1 wife of each head of household every 5 days. The rural market cycle, when most people sold and bought their products, operated on a 5-day cycle. The surveys were focused on the source of cereals consumed in the household (i.e., produced, purchased and received as gifts) and the income sources that the household used in case of purchase (agricultural resources, tree resources, savannah resources, nonfarm and off-farm resources). Household cash incomes for each product corresponded to the value in West African CFA francs (EUR 1 = XOF 655.77) obtained by selling the product. We used local market prices to calculate incomes.

- Agricultural incomes came from the sale of cereals and animals during the surveys.
- Tree incomes derived from NTFP harvesting came mainly from parkland and homestead areas during the surveys.
- Savannah incomes came from wood cutting, processing and selling. They included the gross value of charcoal and sorghum beer prepared with fuelwood sold during this period.
- Nonfarm incomes came from permanent employment and through self-generated income activities.
- Off-farm income was the value of earnings through hiring out of labor and remittances (i.e., all income transfers in cash).

The main statistical analyses used were the descriptive statistics (mean and standard deviation), student testing, Chi-square testing and a generalized linear model (GLM). Student testing was used to highlight the difference between means in the villages according to the households' characteristics (animals owned, cropland size, permanent residents, household size, formal job per household, old age pensions per household). Chi-square tests were used to compare the difference between the villages according to the percentage of the head of households and their wives who were involved in the trade of a given resource. The regression analysis was used to analyze the relationships between cereals purchased and household adaptive strategies used. The dependent variable was cereal purchase and the independent variables were the sales of different products. The odds ratios were used to link household adaptive strategies to cereals purchasing.

Results

Landscape description of the two village territories in Sorobouly and Kalembouly.

Sorobouly covers an area of 2533 ha and Kalembouly covers an area of 2128 ha. Both have a landscape consisting of a mosaic of fields, fallows (more or less wooded according to their age) and woodlands.

In Kalembouly, 70.5 % of the village territory had already been converted into parklands. Arable non-cultivated land, corresponding to the remaining fallows, represented only 2 % of the village territory. The non-arable land covered by woodlands and grasslands still available in the village territory represented 27.5 % of the territory (1.7 % for grasslands and 25.8 % for woodlands). This territory can then be considered as saturated. In Sorobouly, non-cultivated, arable land represented 50.8 % of the territory: 35.1 % of fallows and 15.7 % of woodlands. The fields cover almost the half of the village territory (49.2 %). In contrast with Kalembouly, most of the woodland area of Sorobouly village territory was still suitable for crop production. In summary, field area covered 70.5 % of the Kalembouly territory while fallow and woodland covered 50.8 % of the Sorobouly territory.

According to the forest inventories, species diversity in Sorobouly was slightly higher than in Kalembouly (95 versus 85 tree species). Important differences in density were observed between the two landscapes. In the fields, the average number of stems per hectare was almost the same (22 ± 14 stems/ha in Kalembouly and 19 ± 22 stems/ha in Sorobouly). But in the woodlands areas, the tree density was much higher in Sorobouly (770 ± 549 stems/ha) than in Kalembouly (414 ± 381 stems/ha). The fallows show the same trend: 600 ± 395 stems/ha in Sorobouly and 247 ± 257 stems/ha in Kalembouly. Each standard deviation is above half of each mean; this shows that there is a strong variation of tree densities inside each landscape's elements of the villages' territories. Two species were identified as being particularly important for food security during the participatory workshops in this region: the shea tree (*Vitellaria paradoxa*) and the *néré* (*Parkia biglobosa*). In Sorobouly, the shea tree density was 78 ± 139 trees/ha in the woodlands, 84 ± 111 stems/ha in the fallows and 16 ± 12 trees/ha in the fields. In Kalembouly, we counted 57 ± 60 shea trees/ha in the woodlands, 41 ± 28 trees/ha in the fallows, and 10 ± 9 trees/ha in the fields. The density of *Parkia biglobosa* in Sorobouly was 4 ± 10 trees/ha in the woodlands areas, 4 ± 10 trees/ha in the fallows and 1.3 ± 3 trees/ha in the fields. In Kalembouly, the density of *Parkia biglobosa* was 4 ± 9 stems/ha in the woodlands, 3 ± 7 stems/ha in the fallows and 0.6 ± 1.4 trees/ha in the fields. According to the standard deviation, we noted that the densities of shea trees and *néré* trees also varied strongly in both village territories.

Villages profiles based on households characteristics

The differences in assets between the two villages were significant in terms of ownership of oxen, pigs, poultry and the size of land for cash cropping (Table 1). Those two factors are particularly suitable for comparing the agrarian systems of the two villages as they are often linked to the change from food-producing agriculture to commercial farming. The average cash cropland size per capita is significantly higher in Kalembouly than in Sorobouly, while the average food cropland size per capita in Kalembouly was higher but not statistically different to that of Sorobouly. The average number of oxen per household was significantly higher in Kalembouly than in Sorobouly—70.9 % of households in Kalembouly owned oxen while 50 % owned oxen in Sorobouly. Those two factors demonstrate a more cotton-orientated and mechanized agrarian system in Kalembouly. In Sorobouly, 43.1 % of households owned pigs while in Kalembouly the percentage of household-owning pigs was just 14.5 %. In Sorobouly, the average number of pigs per household was significantly higher than in Kalembouly as there are more practicing Muslims in Kalembouly than in Sorobouly.

Table 1 Households characteristics in Kalembouly and Sorobouly

Household variable	Villages	
	Kalembouly	Sorobouly
% of households owning oxen	70.9	50.0
Oxen per household (all)	3.2 ± 4.3^a	1.9 ± 3.0^b
Cash cropland size per capita (all)	0.5 ± 0.4^a	0.2 ± 0.1^b
% of household owning pigs	14.5	43.1
Pigs per household (all)	0.2 ± 0.7^a	2.3 ± 3.1^b
% of households owning poultry	89.0	87.9
Poultry per household (all)	9.7 ± 6.8^a	13.6 ± 8.6^b
% of household owning goats	78.1	60.3
Goats per household (all)	3.5 ± 4.1^a	3.7 ± 5.6^a
% of households owning sheep	40.0	41.3
Sheep per household (all)	2.5 ± 4.9^a	2.3 ± 4.0^a
Food cropland size per capita (all)	0.7 ± 0.6^a	0.5 ± 0.4^a
Formal jobs per household	0.0 ± 0.0^a	0.0 ± 0.0^a
Pensions per household	0.0 ± 0.0^a	0.1 ± 0.0^a
Permanent residents per household	6.2 ± 2.2^a	6.8 ± 2.5^a

Values in the same line, with different superscript letters are statistically significantly different (*student-test*)

Our results show significant differences with regard to the time of full consumption of the food reserve (i.e., empty granaries). The proportions of households with empty granaries were higher in both villages for the period July–October 2012. This period was the most difficult for both villages, with 17 % of the sampled households reporting completely empty granaries in Sorobouly (10 households) and 18 % reporting empty granaries in Kalembouly (11 households). During the food shortage period from July–October 2013, only one of those households in Kalembouly and three households in Sorobouly purchased cereals.

Households' livelihoods activities and the risk of food insecurity

The gender segregated analysis of households activities show differentiated responsibilities for food security. The first difference was in terms of agricultural production. During the rainy season, male and female household members generally work together in the household fields to produce cereals. A limited number of women have their own plot in the fields where they generally grow cereals and/or groundnuts. However, in time of scarcity and when the harvested grain is completely consumed, women were responsible for providing cereals for daily meals. Male

Table 2 Percentage of male heads of households in sales of forest and agricultural products and other income-generating activities in Kalembouly (K−) and Sorobouly (S+)

Resource	FSP2012		FSP2013		NFSP2013		NFSP2014	
	K−	S+	K−	S+	K−	S+	K−	S+
Cereal	0.0[a]	0.0[a]	67.2[a]	43.1[b]	67.2[a]	31.0[b]	83.6[a]	56.9[b]
Oxen	1.7[a]	0.0[a]	21.8[a]	15.5[b]	10.9[a]	0.0[b]	3.6[a]	1.7[b]
Small livestock	25.4[a]	8.6[b]	47.3[a]	29.3[b]	49.1[a]	25.8[b]	32.7[a]	31.0[a]
Poultry	36.4[a]	34.5[a]	61.8[a]	55.2[a]	54.5[a]	37.9[a]	43.6[a]	44.8[a]
Off-farm activities	18.2[a]	8.6[a]	23.6[a]	10.3[b]	40.0[a]	70.0[b]	30.9[a]	36.2[a]
Nonfarm activities	12.7[a]	6.9[a]	25.5[a]	34.5[b]	43.6[a]	50.0[b]	5.5[a]	32.7[b]
Shea nuts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parkia seeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuelwood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Charcoal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum beer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Values in the same line, within each period, with different superscript letters are statistically significantly different (Chi-square test; *K−* Kalembouly; *S+* Sorobouly)

FSP food shortage period, *NFSP* non-food shortage period

heads of households were not responsible for providing cereals for the family in case of shortages. Our results show that men rarely bought cereals, even during food shortage periods. When granaries became empty during food shortage periods, it was the women's responsibility to buy cereals with the incomes they had generated from their own activities. The second difference was related to collection and selling of tree and savannah resources, which were shown to be exclusively women's activities in our results (Table 2).

Between July and October (FSP2012 and FSP2013), at least 10 % of the surveyed women sold a commodity (e.g., shea nuts or butter, fuelwood, charcoal, sorghum beer, small livestock) they had grown or produced and performed nonfarm activities (Table 3).

The most important tree resource from parklands sold by women was shea nuts. Women sold rarely shea butter and *soumbala* a Parkia seed-based condiment. These products are often prepared and consumed or shared as gifts during festive moment, after giving birth and during funerals. More women sold shea nuts in food shortage periods but this period is also the period for gathering fruit. The percentage of women selling shea nuts was higher in Kalembouly but the difference was only statistically significant in the 2012 food shortage period where more households were at risk of food insecurity. A total of 82 and 50 %, respectively, of women living in households at high risk of food insecurity in Kalembouly and in Sorobouly sold shea nuts during the 2012 food shortage period. This represents, respectively, 15 % (nine households) and 8 % (five households) that must sell shea nuts to buy cereals in both villages. In 2013, a better climatic year, the high proportion of women selling shea nuts in both villages was due to higher production of *Vitellaria paradoxa* than in 2012 and the offer of a local company to buy the nuts from the women.

The most important woodlands products sold by women were fuelwood and charcoal. Even if the trees in parklands provided some fuelwood, the fuelwood and charcoal sold by women came from woodlands and fallows in both villages. We observed a seasonal effect on fuelwood sale in both villages. The differences between the percentages of women selling fuelwood were significantly higher in Sorobouly in all seasons. Just over half (52 %) of women in Sorobouly sold fuelwood in the 2012 food shortage period. Our results show that 80 and 10 %, respectively, of women living in households at high risk of food insecurity in Sorobouly sold fuelwood and charcoal during the 2012 food shortage period. This represents, respectively, 13 % (8 households) that must sell fuelwood to buy cereals and 6 % (1 household) that must sell charcoal to buy cereals. Women in Kalembouly did not sell any fuelwood because of the decline in the area of savannah woodlands in Kalembouly and the scarcity of fuelwood.

Conversely, no significant seasonal effects were observed in the sale of cereals in both villages and across all seasons of the year. However, in Kalembouly, the number of women involved in cereals sales was significantly higher than in Sorobouly. Women living in households at high risk of food insecurity did not sell cereals during the food shortage periods in both villages. Many women who had their own cereal fields could have sold their cereals when they judged that the cereal supply in their household granaries was sufficient to feed their family. In Kalembouly, more women owned their own fields than in Sorobouly. Less than 10 % of women in the two villages sold groundnuts and small livestock (sheep, goats and pigs) during food shortage periods. But the sale of

Table 3 Percentage of women involved in sales of forest and agricultural products and other income-generating activities in Kalembouly (K−) and Sorobouly (S+)

Resource	FSP2012		FSP2013		NFSP2013		NFSP2014	
	K−	S+	K−	S+	K−	S+	K−	S+
Cereal	82.0[a]	17.2[b]	100[a]	24.1[b]	89.1[a]	24.1[b]	98.2[a]	81.0[b]
Ground nut	7.3[a]	6.9[a]	9.1[a]	5.2[a]	3.6[a]	18.9[b]	10.9[a]	55.2[b]
Shea nut	70.9[a]	31.0[b]	85.5[a]	89.6[a]	12.7[a]	3.4[a]	1.8[a]	5.2[a]
Fuelwood	3.6[a]	51.7[b]	0.0[b]	36.2[b]	3.6[a]	36.2[b]	0.0[a]	27.6[b]
Charcoal	5.4[a]	27.6[b]	1.8[a]	39.6[b]	1.8[a]	32.7[b]	3.6[a]	13.2[b]
Sorghum beer	7.2[a]	50.0[b]	9.1[a]	37.9[b]	10.9[a]	41.3[b]	5.4[a]	46.5[b]
Nonfarm activities	14.5[a]	15.5[a]	0.0[a]	12.1[b]	21.8[a]	24.1[a]	5.4[a]	5.2[a]
Small livestock	16.4[a]	1.7[b]	16.4[a]	6.9[a]	3.6[a]	3.4[a]	7.2[a]	8.6[a]
Poultry	3.6[a]	5.1[a]	3.6[a]	3.4[a]	7.3[a]	3.4[a]	5.4[a]	1.7[a]
Parkia seeds	3.6[a]	5.1[a]	0.0[a]	1.7[a]	3.6[a]	0.0[a]	0.0[a]	0.0[a]
Off-farm activities	1.8[a]	3.4[a]	7.2[a]	5.2[a]	5.4[a]	5.2[a]	09.9[a]	1.7[b]

Values in the same line, within each period, with different superscript letters are statistically significantly different (Chi-square test; *K−* Kalembouly; *S+* Sorobouly)

FSP food shortage period, *NFSP* non-food shortage period

small livestock could be an adaptive strategy for climate variability. While no women living in households at high risk of food insecurity in Sorobouly sold small livestock during the 2012 food shortage period, 36.4 % of women living in these kinds of households in Kalembouly sold small livestock.

Dolo is a traditional, sorghum-based beer that is prepared mainly by women in the villages in all seasons. The percentage of women preparing this beverage is significantly higher in Sorobouly than in Kalembouly in all seasons. Its preparation requires a significant amount of fuelwood, which is not available in Kalembouly. Additionally, the Muslim religion is more important to people in Kalembouly than those in Sorobouly. As a result, the percentage of women preparing this beverage is significantly higher in Sorobouly than in Kalembouly. However, we found no difference in the number of women (20 % in both sites) selling sorghum beer during the 2012 food shortage period in the households at high risk.

Links between food insecurity and the trade of forest products

Based on our previous results showing that male heads of households did not sell tree and woodland products during the food shortage period, we conducted an analysis that focused on the livelihood activities of women, in order to better understand the linkages between food shortages and available forest and tree resources.

The results of this analysis (Table 4) show that, in Sorobouly, women living in households with a high risk of food insecurity and who sold fuelwood were 3.15 times (odds ratio = 3.15; $p = 0.\ 01175$; 95 % confidence interval = 1.2–8.4) more likely to buy cereals than those who did not sell fuelwood. Additionally, and although the density of shea trees is high in Sorobouly, women used more fuelwood than shea nuts to cover their needs in cereals. This might be because fuelwood collection in the fallow and woodland areas requires less right of access in contrast to shea nut collection in the parklands. Women sold poultry and charcoal to generate money to purchase cereals but the link is weaker than for sale of shea nuts and fuelwood.

In Kalembouly, women living in households at high risk of food insecurity and who sold shea nuts were four times (odds ratio = 3.95; $p = 0.000367$; 95 % confidence interval = 1.8–8.5) more likely to buy cereals than those who did not sell shea nuts. In this village where wood is scarce, women tend to substitute the products of woodlands with tree products from parklands. Petty trading was also used to buy cereals but the link was weaker.

In Sorobouly, savannah resources were the primary source of cash income in the 2012 food shortage period for all the women surveyed (60). Their sale generated a total income of XOF 6.624 per women per month and accounted for 77 % of the total products sold during this period. The second income source is agriculture products: XOF 838 was earned per women per month, with a contribution of 10 % to the total resources sold in this period. Nonfarm resources (XOF 660 for 8 %), tree resources from the parkland (XOF 428 for 5 %), and off-farm resources (XOF 65 for 0.6 %) contribute, respectively, in the third, fourth and fifth positions to the total products sold. For women living in the households in high risk of food insecurity (10/60) in this village, savannah resources were also the primary source of cash incomes during this period generating

Table 4 Influence of women's livelihoods strategies on the purchases of cereals in 2012 food shortage period in Sorobouly and Kalembouly

	Sorobouly		Kalembouly	
Kalembouly	z value	Pr(>|z|)	z value	Pr(>|z|)
(Intercept)	−4.223	2.41e−05****	−7.004	2.49e−12****
Fuelwood	2.375	0.0175**	1.570	0.116523
Shea nut	0.873	0.3826	3.563	0.000367****
Charcoal	−1.664	0.0961*	0.509	0.610783
Petty trading	0.494	0.6213	2.240	0.025122**
Parkia seeds	−0.011	0.9915	−0.016	0.987530
Sorghum beer	−1.583	0.1135	1.604	0.108805
Groundnut	−0.009	0.9932	0.603	0.546504
Small livestock	−0.004	0.9972	1.592	0.111341
Poultry	1.692	0.0906*	0.126	0.899441
	LRT X^2 = 26,797; $df = 9$; $p = 0.001511$		LRT X^2 = 29,232; $df = 9$; $p = 0.0005922$	

Significance codes: **** 0.001; *** 0.01; ** 0.05; * 0.1

XOF 5043 per women per month and accounting for 64 % of the total products sold in this period. This income source is followed by nonfarm resources (XOF 1446 for 10 %), off-farm resources (XOF 875 for 8.8 %), tree resources in parkland (XOF 430 for 5 %) and agricultural resources (XOF 312 for 3.4 %).

For all the women in the sample in Kalembouly, agricultural resources were the primary source of cash income (XOF 3400 per women per month), representing 61 % of the total products sold in this period. Tree resources sales were the second source of income (XOF 1542 per women per month) and contributed 16 % to the total for products sold in this period. Nonfarm resources (XOF 664 for 12 %), savannah resources (XOF 590 for 10 %) and off-farm resources (XOF 23 for 0.4 %) were the third, fourth and fifth income-generating sources of Kalembouly women's incomes, respectively. For women living in the households at high risk of food insecurity in this village (11/60), the primary source of incomes during the same period were the tree resources originated from parkland. Their sale contributes XOF 2297 to each women's income per month and represents 37 % of the total products sold. They are followed by agricultural resources (accounted for 24 % and amounting to XOF 1534), savannah resources (XOF 1302 for 22 %), nonfarm resources (XOF 886 for 15 %) and off-farm resources (XOF 114 for 1.7 %).

For the households at high risk of food insecurity, in both villages the tree resources sale is the primary source of women's incomes. However, in Sorobouly, while the incomes generated from savannah products are the primary source of incomes for all women, those at high risk of food insecurity earn less money from tree product sales than the average, probably due their more restricted access to this plentiful resource. Conversely, in Kalembouly, which was more deforested than Sorobouly, tree products sales is the primary source of income only for women at high risk of food insecurity and they generated higher incomes for these women than for the others whose primary source of income is agriculture.

Discussion

At equal agroclimatic conditions, the higher population density in Kalembouly (69 inhabitants per km^2) compared to Sorobouly (24 inhabitants per km^2) combined with a higher area of cash and food cropland owned per capita (0.5 ha and 0.7 ha for Kalembouly compared to 0.2 and 0.5 ha for Sorobouly) led to an important loss of natural vegetation in the Kalembouly village territory. The results show a trend of increasing agricultural mechanization and diversification in Kalembouly on the basis of extensive agricultural practices. Apart from the conversion of natural vegetation to parklands, Kalembouly is better connected to markets and better organized in its associative life. All of these elements shape the landscape diversity differently in the two villages with a field matrix in Kalembouly (with 70 % of the area marked out as permanent fields) and a woodland matrix in Sorobouly (with almost 50 % of the arable land not yet cultivated). Tree density in the parklands is not significantly different in both villages, which confirms the results found by Gautier et al. (2006) in northern Cameroon and in Chad. However, despite the higher level of mechanization, we observed a slightly higher tree density in parklands in Kalembouly. This might be explained by efforts of farmers in this village to compensate the important loss in trees ecosystem services by increasing tree density in the parklands, as observed in other regions in the Sahel (Gautier et al. 2006).

Shea trees were found to be the most widespread trees in both village territories as observed by Lamien et al. (2005) and Fischer et al. (2011) in other regions in Burkina Faso. The density of shea trees was slightly higher in Sorobouly than in Kalembouly, but they were not used at times of food insecurity due to the abundance of the remaining woodlands.

As noted by Shackleton et al. (2007), our study confirms that the use of tree and savannah products prevent the most vulnerable households from falling into deeper food insecurity by depleting their assets. In African dryland areas, similar findings have been observed and confirm the fact that the use of cash income from forest resources is important in overcoming food shortages in areas where food crops face greater risks of climate variability. For instance, in Mulanje district in Malawi, Fisher et al. (2010) found that 25 % of the rural population sold non-timber forest products to buy food in the hungry period. In the semiarid area of Sudan, 62 % of collectors spent their incomes from *Adonsonia digitata* (baobab) fruits on food, 100 % spent their incomes from *Ziziphus spina-christi* and from *Balanites aegyptiaca* on food (Adam et al. 2013). In the dry woodlands of Borona, southern Ethiopia, the sale of gums and resins in food shortage periods made a significant contribution to household income (for purchase of food items) (Worku et al. 2011).

Our results highlight that tree and savannah resources are the primary income sources for the most vulnerable households, and for women in case of food shortage, as argued in other studies in Burkina Faso (Fisher et al. 2010; Roncoli et al. 2001; Thiombiano et al. 2012) and in the Sahel (Mortimore and Adams 2001). However, those studies were conducted in areas with less favorable agro-climatic conditions and less natural resources than the current study. There is thus a smaller proportion of households at risk of food insecurity in our case study (10 of 60 households in Sorobouly and 11 of 60 households in Kalembouly) than in northern Burkina Faso. However, even if food shortage periods are not as severe as those in the central plateau and the northern part of Burkina Faso, our results highlight the importance of natural resources for households at risk of food shortage even in more favorable agroclimatic conditions. Additionally, these improved conditions allow us to explore the link between the adaptive strategies for food shortages, the landscape composition and structure and the available resources that are more abundant than in the northern regions.

The role of the safety net of forest and trees resources is discussed in the literature. While earlier studies (Angelsen and Wunder 2003; Shackleton and Shackleton 2004; Worku et al. 2011) confirm the safety net role of forest, new findings are revisiting this common wisdom. Wunder et al. (2014) argue that although more forest extraction is a more likely response to cope with multiple shocks and to alleviate income shortfalls, this is relevant only for a minority of cases. Our study did not confirm the latter and shows that for the most vulnerable, savannah and tree resources are crucial in times of crisis. Three arguments can explain the differences in findings with regard to the role of safety net. First, our study took place directly after an extreme event and during its impact on the food shortage situation and was based on a triangulation of methods using a questionnaire every 5 days and direct observation. One limitation of large surveys is that if they are not done immediately after a crisis, they rely on the memory of the respondents regarding the resources used to cope with the crisis, which might bias the results. Even if it is difficult to avoid some biased responses from people expecting some aid just after a crisis, these biases were minimized by regular monitoring of the households and women's strategies to cope with food shortages with direct observations and measurements. Second, the study focuses mostly on women; with this gender-sensitive approach, we directly targeted the most vulnerable forest users. Forests might be not that important for all households, but in the context of Burkina Faso, where women are responsible for ensuring food security in times of crisis, they are still a crucial safety net for women in tackling food insecurity. Intra-households' differences in roles and vulnerabilities (due to gender or other factors) is key, and the selection of households' members the survey targeted is crucial. Third, our study considered the role of Savannah resources and included the role of trees in parklands which has been shown to be important as a safety net.

Apart from a few exceptions, the compensation trend to change from a savannah to parkland landscape matrix has not been thoroughly studied in terms of its role in coping with the risk of food insecurity. Gautier et al. (2006) have shown in the case of northern Cameroon and Chad, there is a trend to compensate for the loss of tree diversity in woodlands by enhancing biodiversity in the parkland that replaces woodlands. In this paper, we studied food security using the landscape structure and composition as an entry point. Our findings show that landscape structure and composition matter as the transition from a savannah to a parkland matrix has an important impact on food security and shapes the adaptive strategies to cope with food shortages. This study contributes to understand more the linkages between food shortages and landscape composition and structure. However, and due to the limited number of landscapes considered, more studies are needed to confirm the trends identified in this study.

Several studies demonstrated that people living close to forests generate more income from forest products (Angelsen and Kaimowitz 1999; Feto 2009; Kamanga et al. 2009). Our results show that different patterns of access right to forest might play a bigger role than the presence of and proximity to forest. While the income generated from savannah products are the primary source of incomes for all women considered in the study from the savannah product in Sorobouly, those at high risk of food insecurity generate less income than average, probably due their greater restricted access to resources. There are several discussions in the literature around the question of wealth and the use of forests, showing that only the wealthiest derive greater absolute value from forest resources (Heubach et al. 2011; Mamo et al. 2007; Vedeld et al. 2007). In Kalembouly, the tree products from parklands are the primary source of income for the women at high risk of food insecurity, who generate higher income than the women in less food-insecure households, whose primary source of income is agriculture.

The gender dimension of forest resources for coping with drought in the region was documented by Djoudi and Brockhaus (2011). Our findings confirm the central importance of women's role in household food security during food shortage periods even in a more favorable agroclimatic environment. Women must provide food in the form of cereals during food shortage periods when the granaries are empty, even if the household heads (men) can contribute also. Women in general have always relied more on forest products than men have (Byron and Arnold 1999; Cavendish 2000; Shackleton et al. 2002; Shackleton and Shackleton 2006). In southern Ethiopia, children and women are responsible for collecting, transporting and selling gums and resins (Worku et al. 2011). In South Africa, they are the primary producers and traders of brushes and marula beer (Shackleton and Shackleton 2004) and in the Cape Province of South Africa, they are responsible for collecting wild vegetables (Cocks and Wiersum 2003). Our study demonstrates that women not only rely on forest products as a source of income, (e.g., in Sorobouly where women produce some charcoal as a diversification activity) but they rely on them in times of food shortage as their primary adaptive strategy.

Conclusion

In the Sudano-Sahelian area, landscape structure and composition are important for rural household food security and ability to cope with crop food shortages, as demonstrated in this study in southwest Burkina Faso. During a period of food shortage, households with empty granaries developed differentiated adaptive strategies according to their specific landscape composition and diversity. In the village territory where there are still large areas of woodland, women at high risk of food insecurity sell wood to buy cereals during food shortage periods. In the village territories where there are very few woodlands left, women in the same situation collect and sell parklands' tree products such as shea nuts in order to buy cereals. When the landscape changes from a woody to a cropping area, these women change their adaptive strategies to cope with climate variability and compensate for the loss of natural vegetation and associated forest products with agroforestry products. However, in the landscapes with a parkland matrix, a growing scarcity of fuelwood represent a challenge for women in terms of the long walking distances to collect fuelwood and the additional cost of purchasing it in the market. Hence, the households at high risk of food insecurity that rely most on tree products could be constrained in their adaptive strategies if the forest law is applied in a coercive way with no tolerance for the most vulnerable. National policies must consider tree and forest resources as part of the range of food security resources and strategies that are used to cope with food insecurity. In order to reconcile food security and biodiversity conservation and gender equitable outcomes, efficient and gender-sensitive natural management and planning and development policies are needed to preserve the role of savannah and parkland resources and trees to enhance adaptive capacity and decrease the risk of food insecurity among the most vulnerable communities.

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References

Adam YO, Pretzsch J, Pettenella D (2013) Contribution of non-timber forest products livelihood strategies to rural development in drylands of Sudan: potentials and failures. Agric Syst 117:90–97. doi:10.1016/j.agsy.2012.12.008

Angelsen A, Kaimowitz D (1999) Rethinking the causes of deforestation: lessons from economic models. World Bank Res Obser 14:73–98. doi:10.1093/wbro/14.1.73

Angelsen A, Wunder S (2003) Exploring the forest-poverty link: key concepts, issues, and research implications. Center for International Forestry Research, Bogor, Indonesia. CIFOR Occasional Paper. doi:10.17528/cifor/001211

Arnold M, Powell B, Shanley P, Sunderland TCH (2011) Forests, biodiversity and food security. Int Forest Rev 13:259–264. doi:10.1505/146554811798293962

Byron N, Arnold M (1999) What futures for the people of the tropical forests? World Dev 27:789–805. doi:10.1016/S0305-750X(99)00025-X

Cavendish W (2000) Empirical irregularities in the poverty–environment relationship of rural households: evidence from Zimbabwe. World Dev 28:1979–2003. doi:10.1016/S0305-750X(00)00066-8

Cocks ML, Wiersum KF (2003) The significance of plant diversity to rural households in Eastern Cape Province of South Africa. For Trees Livelihoods 13:39–58. doi:10.1080/14728028.2003.9752443

Colfer CJP, Sheil D, Kaimowitz D, Kishi M (2006) Forests and human health in the tropics: some important connections. Unasylva 224:57

Djoudi H, Brockhaus M (2011) Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. Int Forest Rev 13:123–135. doi:10.1505/146554811797406606

Djoudi H, Vergles E, Blackie RR, Koame CK, Gautier D (2015) Dry forests, livelihoods and poverty alleviation: understanding current trends. Int Forest Rev 17(S2):54–69. doi:10.1505/146554815815834868

Egoh BN, O'Farrell PJ, Charef A, Josephine Gurney L, Koellner T, Nibam Abi H, Egoh M, Willemen L (2012) An African account of ecosystem service provision: use, threats and policy options for sustainable livelihoods. Ecosyst Serv 2:71–81. doi:10.1016/j.ecoser.2012.09.004

Feto MS (2009) The role of non timber forest products to rural livelihoods and forest conservation: a case study at Harana Bulluk district, Oromia national regional state, Ethiopia. Dissertation, Wondo Genet College of Forestry and Natural Resources, Ethiopia

Fischer C, Kleinn C, Fehrmann L, Fuchs H, Panferov O (2011) A national level forest resource assessment for Burkina Faso: a field based forest inventory in a semiarid environment combining small sample size with large observation plots. For Ecol Manag 262:1532–1540. doi:10.1016/j.foreco.2011.07.001

Fisher M, Shively GE (2005) Can income programs reduce tropical forest pressure? Income shocks and forest use in Malawi. World Dev 37(7):1115–1128. doi:10.1016/j.worlddev.2005.04.008

Fisher M, Chaudhury M, McCusker B (2010) Do forests help rural households adapt to climate variability? Evidence from southern Malawi. World Dev 38:1241–1250. doi:10.1016/j.worlddev.2010.03.005

Garrity DP, Akinnifesi FK, Ajayi OC, Weldesemayat SG, Mowo JG, Kalinganire A, Larwanou M, Bayala J (2010) Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Security 2:197–214. doi:10.1007/s12571-010-0070-7

Gautier D, Karr N (2000) Protocole pour l'opération gestion des resources végétales non cultivées et de l'espace dans et autour des terroirs PRASAC. CIRAD-Forêt, Montpellier

Gautier D, Bazile D, Picard N (2006) Interactions between Sahelo-Sudanian savannas and parklands in space and time. How it affects biomass and biodiversity in regards to stakeholder strategies. In: Mistry J, Berardi A (eds) Placing people back into nature: lessons from savannas and dry forests. Ashgate, London, pp 227–240

GIEC (2007) Climate change 2007: synthesis report. Contribution des groupes de travail I, II et III au quatrième rapport d'évaluation du groupe d'experts intergouvernemental sur l'évolution du climat. GIEC, Geneva, Switzerland

Harris FM, Mohammed S (2003) Relying on nature: wild foods in northern Nigeria. Ambio 1:24–29. doi:10.1579/0044-7447-32.1.24

Hautdidier B, Gautier D (2005) What local benefits does the implementation of rural wood markets in Mali generate? In: Ros-Thonen MAF, Dietz AJ (eds) African forests between nature and livelihood resources: interdisciplinary studies in conservation and forest management. Edwin Mellen Press, Ceredigion, pp 191–220

Heubach K, Wittig R, Nuppenau E-A, Hahn K (2011) The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural West African communities: a case study from northern Benin. Ecol Econ 70:1991–2001. doi:10.1016/j.ecolecon.2011.05.015

Janin P (2003) Soudure alimentaire et gestion sociétale des risques en zone sahélienne (Burkina Faso). Quatrième Conférence Africaine sur la Population 'Population et pauvreté en Afrique: réagir aux défis du XXI° siècle'

Janin P (2008) L'insécurité alimentaire en Afrique de l'Ouest: cadres politiques et options techniques pour l'action. IRD, Montpellier

Janin P, Martin-Prevel Y (2006) Des indicateurs à l'action: vulnérabilité alimentaire et situation nutritionnelle en milieu rural sahélien burkinabé. Can J Afr Stud 40:443–461. doi:10.1080/00083968.2006.10751401

Kamanga P, Vedeld P, Sjaastad E (2009) Forest incomes and rural livelihoods in Chiradzulu district, Malawi. Ecol Econ 68:613–624. doi:10.1016/j.ecolecon.2008.08.018

Lamien N, Ouédraogo SJ, Diallo OB, Guinko S (2005) Productivité fruitière du karité (*Vitellaria paradoxa* Gaertn. CF, Sapotaceae) dans les parcs agroforestiers traditionnels au Burkina Faso. Fruits 59:423–429. doi:10.1051/fruits:2005004

Mamo GE, Sjaastad E, Vedeld P (2007) Economic dependence on forest resources: a case from Dendi district, Ethiopia. For Policy Econ 9:916–927. doi:10.1016/j.forpol.2006.08.001

Maxwell DG (1996) Measuring food insecurity: the frequency and severity of "coping strategies". Food Policy 21:291–303. doi:10.1016/0306-9192(96)00005-X

McConnell R (2008) Links between national forest programmes and poverty reduction strategies. Forestry policy and institutions working paper. Food and Agriculture Organization of the United Nations

Mortimore MJ, Adams WM (2001) Farmer adaptation, change and 'crisis' in the Sahel. Global Environ Change 11:49–57. doi:10.1016/S0959-3780(00)00044-3

Ndoye O, Tieguhong JC (2004) Forest resources and rural livelihoods: the conflict between timber and non-timber forest products in the Congo Basin. Scand J Forest Res 19:36–44. doi:10.1080/14004080410034047

Oksanen T, Mersmann C (2003) Forest in poverty reduction strategies: an assessement of PRSP processes. In: Oksanen T, Pajari B, Tuomasjukka T (eds) Sub-Saharan Africa. Forests in poverty reduction strategies: capturing the potential. EFI Proceedings, No. 47, European Forest Institute, Joensuu, pp 121–158

Payne P, Lipton M (1994) How third world rural households adapt to dietary energy stress: the evidence and the issues. IFPRI Food Policy Rev, Washington

Powell B, Hall J, Johns T (2011) Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania. Int For Rev 13:305–317. doi:10.1505/146554811798293944

Pramova E, Locatelli B, Brockhaus M, Fohlmeister S (2012a) Ecosystem services in the national adaptation programmes of action. Clim Policy 12(4):393–409. doi:10.1080/14693062.2011.647848

Pramova E, Locatelli B, Djoudi H, Somorin OA (2012b) Forests and trees for social adaptation to climate variability and change. Wiley Intdisc Re Clim Change 3(6):581–596. doi:10.1002/wcc.195

RGPH (2006) Recensement général de la population et de l'habitation de 2006. Burkina Faso, Ouagadougou

Roncoli C, Ingram K, Kirshen P (2001) The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. Climate Res 19:119–132

Ros-Tonen MAF, Wiersum KF (2003) The importance of non-timber forest products for forest-based rural livelihoods: an evolving research agenda. In: The international conference on rural livelihoods, forests and biodiversity

Shackleton C, Shackleton S (2004) The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. S Afr J Sci 100:658–664

Shackleton CM, Shackleton SE (2006) Household wealth status and natural resource use in the Kat River valley, South Africa. Ecol Econ 57:306–317. doi:10.1016/j.ecolecon.2005.04.011

Shackleton SE, Shackleton CM, Netshulvhi TR, Geach BS, Ballance A, Fairbanks DH (2002) Use patterns and value of savanna resources in three rural villages in South Africa. Econ Bot 56:130–146. doi:10.1663/0013-0001(2002)056[0130:UPAVOS]2.0.CO;2

Shackleton CM, Shackleton SE, Buiten E, Bird N (2007) The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. For Policy Econ 9:558–577. doi:10.1016/j.forpol.2006.03.004

Somorin OA (2010) Climate impacts, forest-dependent rural livelihoods and adaptation strategies in Africa: a review. Afr J Environ Sci Tech 4:903–912

Thiombiano DNE, Lamien N, Dibong DS, Boussim IJ, Belem B (2012) Le rôle des espèces ligneuses dans la gestion de la soudure alimentaire au Burkina Faso. Sécheresse 23:86–93. doi:10.1684/sec.2012.0341

Traore O, Some AN, Traore K, Nikiema PP, Some K (2007) State and trends of woody vegetation cover inthe cotton based farming system zone of Western Burkina Faso. Int J Biol Chem Sci 1:43–53. doi:10.4314/ijbcs.v1i1.39697

Vedeld P, Angelsen A, Bojö J, Sjaastad E, Kobugabe Berg G (2007) Forest environmental incomes and the rural poor. For Policy Econ 9:869–879. doi:10.1016/j.forpol.2006.05.008

Verchot LV, Van Noordwijk M, Kandji S, Tomich T, Ong C, Albrecht A, Mackensen J, Bantilan C, Anupama KV, Palm C (2007) Climate change: linking adaptation and mitigation through agroforestry. Mitig Adapt Strat Glob Change 12:901–918. doi:10.1007/s11027-007-9105-6

Vinceti B, Eyzaguirre P, Johns T (2008) The nutritional role of forest plant foods for rural communities. In: Colfer CJP (ed) Human health and forests: a global overview of issues, practice and policy. Earthscan, London, pp 63–96

Warner K (2000) Foresterie et moyens d'existence durables. Unasylva 58 226/227:80–87

Worku A, Lemenih M, Fetene M, Teketay D (2011) Socio-economic importance of gum and resin resources in the dry woodlands of Borana, southern Ethiopia. For Trees Livelihoods 20:137–155. doi:10.1080/14728028.2011.9756703

Wunder S (2001) Poverty alleviation and tropical forests: what scope for synergies? World Dev 29:1817–1833. doi:10.1016/S0305-750X(01)00070-5

Wunder S, Börner J, Shively G, Wyman M (2014) Safety nets, gap filling and forests: a global-comparative perspective. World Dev 64:S29–S42. doi:10.1016/j.worlddev.2014.03.005

Yemiru T, Roos A, Campbell BM, Bohlin F (2010) Forest incomes and poverty alleviation under participatory forest management in the Bale Highlands, southern Ethiopia. Int Forest Rev 12:66–77. doi:10.1505/ifor.12.1.66